

## 41 种植物精油对淡色库蚊的熏蒸活性

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**摘要:** 为发现具有较高杀蚊活性的精油, 推动植物精油类卫生杀虫剂的创制, 本研究采用三角瓶熏蒸法测定了 17 科 41 种植物精油对淡色库蚊 *Culex pipiens pallens* 雌成蚊的熏蒸活性, 并进一步采用密闭圆筒法验证其杀虫毒力大小。三角瓶熏蒸法测定表明, 在 12  $\mu\text{L/L}$  浓度下, 留兰香油 (spearmint oil)、薰衣草油 (lavender oil)、山苍子油 (*Litsea cubeba* oil) 等 26 种精油均有较强的熏蒸作用,  $\text{KT}_{50}$  小于 15 min。该 26 种精油用密闭圆筒熏蒸法进一步测定表明, 在浓度为 10  $\mu\text{L/L}$  时, 冬青油 (wintergreen oil)、艾叶油 (blumea oil)、薄荷油 (peppermint oil)、桉叶油 (*Eucalyptus robusta* oil) 和蓝桉油 (*E. globulus* oil) 等植物精油熏蒸活性较强, 其  $\text{KT}_{50}$  分别为 16.91, 21.20, 22.57, 18.43 和 19.48 min。结果证明冬青油、艾叶油、薄荷油、桉叶油和蓝桉油等 5 种精油对淡色库蚊具有较强的熏蒸活性, 具备作为淡色库蚊防控剂开发的潜力, 值得进一步研究。

**关键词:** 淡色库蚊; 植物精油; 熏蒸活性; 卫生杀虫剂; 击倒中时 ( $\text{KT}_{50}$ )

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### Fumigation activity of 41 essential oils against *Culex pipiens pallens* (Diptera: Culicidae)

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**Abstract:** To find the essential oils with high insecticidal activity and promote the development of hygienic insecticides, essential oils from 41 plants belonging to 17 families were evaluated for adulticidal activity against female adults of *Culex pipiens pallens* by airtight fumigation in conical flask and hermetic round canister method. The results showed that 26 essential oils (12  $\mu\text{L/L}$ ) including spearmint oil, lavender oil and *Litsea cubeba* oil were very toxic to the mosquito ( $\text{KT}_{50} < 15$  min) by airtight fumigation in conical flask. Further assay using hermetic round canister method indicated that 5 essential oils (wintergreen oil, blumea oil, peppermint oil, *Eucalyptus robusta* oil and *E. globulus* oil) had high fumigation toxicity at the concentration of 10  $\mu\text{L/L}$ , and their  $\text{KT}_{50}$  values were 16.91, 21.20, 22.57, 18.43 and 19.48 min, respectively. The results demonstrate that wintergreen oil, blumea oil, peppermint oil, *E. robusta* oil and *E. globulus* oil all have high fumigation activity against *C. pipiens pallens*, with the potential to be developed as hygienic insecticides.

**Key words:** *Culex pipiens pallens*; essential oil; fumigation activity; hygienic insecticide; median knockdown time ( $\text{KT}_{50}$ )

淡色库蚊 *Culex pipiens pallens* 为常见吸血骚扰蚊种, 嗜吸人、畜血, 是班氏丝虫病 (Bancroftian filariasis) 的主要传播媒介, 分布广、种群密度高, 严重影响人类的日常生活, 是公共卫生的主要防治对象之一。长期以来, 防治蚊虫以化学合成农药为

主(陆宝麟, 1999; 陆宝麟和赵彤言, 2000)。然而, 随着化学农药的长期使用, 其抗药性问题日益突出(陈志龙等, 2011; 孟凤霞等, 2011; 龚震宇等, 2012), 安全性也备受质疑, 如: 避蚊胺能够影响哺乳动物的神经系统 (Corbel *et al.*, 2009); 高效氯氰

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菊酯对雄性小鼠生殖器官有一定毒性(Wang *et al.*, 2009)。因此,研究开发高效、安全的新型卫生害虫防控剂替代产品已成为生活、生产中的迫切需要。

植物精油(essential oil)是一类植物源次生代谢物质,分子量较小,可随水蒸气蒸出,为具有一定挥发性的油状液体物质,具有来源广、环境友好及低毒等优点,与无公害农药研发理念吻合,尤其是其气味宜人、挥发性好,更适宜于室内卫生害虫的防控。目前,关于精油对卫生害虫防控作用的研究进展较快,如:从芹菜 *Apium graveolens*、葛缕子 *Carum carvi*、莪术 *Curcuma zedoaria*、荜茇 *Piper longum* 和八角 *Illicium verum* 等植物材料中提取的精油对埃及伊蚊 *Aedes aegypti* 成虫均具有毒杀活性(Chaiyasit *et al.*, 2006);刺柏精油、茴芹精油、生姜精油、迷迭香精油对斯氏按蚊 *Anopheles stephensi*、埃及伊蚊和致倦库蚊 *Culex pipiens quinquefasciatus* 均有较高的杀卵活性,肉桂精油对 3 种蚊虫均具有较强的产卵忌避作用(Veena *et al.*, 2005);山苍子 *Litsea cubeba* 中提取的山苍子油(*L. cubeba* oil)对埃及伊蚊和致倦库蚊均有良好的驱避效果,且对埃及伊蚊雌成蚊产卵忌避作用显著(Lalko and Api, 2006; Tawatsin *et al.*, 2006);猫薄荷油主要成分假荆芥内酯对白纹伊蚊 *Aedes albopictus* 和淡色库蚊具驱避作用(郝蕙玲等, 2006);椿叶花椒果实精油主成份为 2-十一酮,对白纹伊蚊和致倦库蚊成蚊及幼虫均具有良好的熏蒸及毒杀效果(张云等, 2009)。然而,目前以精油开发出的卫生害虫防控剂产品较少,且多为驱避剂,如 Termimx<sup>®</sup> ALLCLEAR<sup>®</sup> Sidekick、Super Band<sup>™</sup> 等,对熏蒸剂的开发力度不够。

另外,尽管国内外已开展了植物精油对蚊虫毒杀活性的筛选工作(杨频等, 2004; Trongtokit *et al.*, 2005; Lee *et al.*, 2006; Zhu *et al.*, 2006),但筛选范围有限,且表现出具有开发潜力的精油种类并不多。我国拥有丰富的植物精油资源,含精油的 500 余种芳香植物广泛分布于 20 多个省市,资源优势显著。鉴于此,本研究以淡色库蚊雌成蚊为试虫,对自然资源较为丰富、常见的 17 科 41 种植物精油进行了杀蚊活性评价,为研制新型植物精油类卫生害虫防控剂提供基础资料。

## 1 材料与方法

### 1.1 供试精油

选用 17 科 22 属 41 种植物精油(表 1),均采用

水蒸气蒸馏法制得,于 2012 年 5 月全部购自江西省吉水县水南威霸药用香料油提炼厂。

### 1.2 供试昆虫

淡色库蚊 *C. pipiens pallens* 从北京军事医学科学院引种,在西北农林科技大学无公害农药研究服务中心养虫室内(温度  $26 \pm 1^\circ\text{C}$ , 相对湿度  $65\% \pm 5\%$ , 光周期 12L:12D)饲养,取整齐一致的健康 3 日龄雌成蚊供试。

### 1.3 三角瓶熏蒸法生测试验

采用经典的三角瓶熏蒸法(江志利等, 2002)初步测定 41 种植物精油对淡色库蚊熏蒸活性。在预试验基础上,确定精油的供试剂量为  $12 \mu\text{L/L}$ 。实验具体操作为:先在 330 mL 三角瓶中接入 20 头供试蚊虫,在橡皮塞上固定一块滤纸条( $1 \text{ cm} \times 3 \text{ cm}$ ),并滴加定量精油(熏蒸浓度为  $12 \mu\text{L/L}$ ),迅速塞紧橡皮塞,并计时,每隔 30 s 记录一次被击倒的试虫数。每组处理重复 3 次,同时设空白对照。测试条件:温度  $26 \pm 1^\circ\text{C}$ , 相对湿度  $65\% \pm 5\%$ 。

### 1.4 密闭圆筒熏蒸法生测试验

基于三角瓶熏蒸法测定结果,对  $\text{KT}_{50} < 15 \text{ min}$  的 26 种精油进一步采用密闭圆筒熏蒸法(农业部农药检定所, 2009, 第 2 部分)评价熏蒸效果,实验条件及操作过程同上,仅将熏蒸容器替换为透明塑料圆筒(内径 20 cm, 高 43 cm),熏蒸浓度为  $10 \mu\text{L/L}$ 。

### 1.5 数据统计与分析

采用 SPSS16.0 软件的机率值分析法计算  $\text{KT}_{50}$ 、毒力方程、卡方值、95% 置信限。

## 2 结果与分析

### 2.1 41 种植物精油对淡色库蚊雌成蚊的熏蒸活性

采用三角瓶熏蒸法测定了 41 种精油对淡色库蚊的熏蒸活性,结果见表 2。由表 2 可知,41 种植物精油均对淡色库蚊表现出不同程度的熏蒸活性,其中:冷榨桔子油、红桔油、柠檬草油、薄荷油、冷杉油、桉叶油、紫苏叶油、迷迭香油、白樟油、八角茴香油、山苍子油、蓝桉油、蒸馏桔子油、芳樟油、白兰叶油、冬青油、艾叶油等 17 种精油对淡色库蚊具有很好的熏蒸活性,  $\text{KT}_{50}$  均在 10 min 以内,尤以冬青油的熏蒸活性最好,  $\text{KT}_{50}$  仅为 4.01 min;橙叶油、冬柠檬油、香樟油等 14 种精油对淡色库蚊的熏蒸时效一般,  $\text{KT}_{50}$  在 10 ~ 20 min 之间;丁香叶油等 10 种精油熏蒸活性较差,  $\text{KT}_{50}$  在 20 min 以上。

表 1 供试植物精油名录  
Table 1 List of test essential oils from plants

科 Family	属 Genus	种 Species	精油 Essential oil
芸香科 Rutaceae	柑橘属 <i>Citrus</i>	橙 <i>C. sinensis</i>	橙叶油 Petitgrain oil
		桔子 <i>C. reticulata</i>	冷榨桔子油 Cold squeeze mandarin oil
			蒸馏桔子油 Steam distillation mandarin oil
			红桔油 Tangerine oil
		玳玳花 <i>C. aurantium</i>	玳玳花油 Dai-dai flower oil
			玳玳叶油 Dai-dai leaf oil
		柠檬 <i>C. limon</i>	冬柠檬油 Winter lemon oil
			白柠檬油 Lime oil
禾本科 Gramineae	香茅属 <i>Cymbopogon</i>	香茅 <i>C. schoenanthus</i>	香茅油 Citronella oil
		柠檬草 <i>C. citratus</i>	柠檬草油 Lemongrass oil
唇形科 Labiatae	薄荷属 <i>Mentha</i>	薄荷 <i>M. haplocalyx</i>	薄荷油 Peppermint oil
		留兰香 <i>M. spicata</i>	留兰香油 Spearmint oil
	罗勒属 <i>Ocimum</i>	丁香罗勒 <i>O. gratissimum</i>	丁香罗勒油 Eugenol type basil oil
	熏衣草属 <i>Lavandula</i>	熏衣草 <i>L. pedunculata</i>	熏衣草油 Lavender oil
	紫苏属 <i>Perilla</i>	紫苏 <i>P. frutescens</i>	紫苏叶油 <i>P. frutescens</i> leaf oil
	迷迭香属 <i>Rosmarinus</i>	迷迭香 <i>R. officinalis</i>	迷迭香油 Rosemary oil
八角科 Illiciaceae	八角属 <i>Illicium</i>	八角 <i>I. verum</i>	八角叶油 Star anise leaf oil
			八角茴香油 Star anise oil
樟科 Lauraceae	樟属 <i>Cinamomum</i>	肉桂 <i>C. cassia</i>	肉桂油 Cinnamon oil
		芳樟 <i>C. camphora</i>	白樟油 White camphor oil
			芳樟油 Linaloe wood oil
			香樟油 Hosho oil
	木姜子属 <i>Litsea</i>	山苍子 <i>L. cubeba</i>	山苍子油 <i>L. cubeba</i> oil
			松节油 Turpentine oil
松科 Pinaceae	冷杉属 <i>Abies</i>		冷杉油 Fir needle oil
百合科 Liliaceae	葱属 <i>Allium</i>	大蒜 <i>A. sativum</i>	大蒜油 Garlic oil
桃金娘科 Myrtaceae	桉属 <i>Eucalyptus</i>	桉树 <i>E. robusta</i>	桉叶油 <i>E. robusta</i> oil
		细叶桉 <i>E. tereticornis</i>	细叶桉油 <i>E. tereticornis</i> oil
		柠檬桉 <i>E. citriodora</i>	柠檬桉油 Lemon eucalyptus oil
		蓝桉 <i>E. globules</i>	蓝桉油 <i>E. globulus</i> oil
木犀科 Oleaceae	丁香属 <i>Syringa</i>	丁香 <i>S. aromaticum</i>	丁香叶油 Clove leaf oil
			丁香花蕾油 Clove bud oil
败酱科 Valerianaceae	缬草属 <i>Valeriana</i>	缬草 <i>V. officinalis</i>	缬草油 Valerian oil
山茶科 Theaceae	山茶属 <i>Camellia</i>	茶树 <i>C. sinensis</i>	茶树油 Tea tree oil
番荔枝科 Annonaceae	依兰属 <i>Cananga</i>	依兰 <i>C. odorata</i>	依兰油 Ylang ylang oil
木兰科 Magnoliaceae	含笑属 <i>Michelia</i>	白兰 <i>M. alba</i>	白兰叶油 <i>M. alba</i> leaf oil
肉豆蔻科 Myristicaceae	肉豆蔻属 <i>Myristica</i>	肉豆蔻 <i>M. fragrans</i>	肉豆蔻油 Nutmeg oil
冬青科 Aquiffoiaceae	冬青属 <i>Ilex</i>	冬青 <i>I. purpurea</i>	冬青油 Wintergreen oil
菊科 Compositae	蒿属 <i>Artemisia</i>	青蒿 <i>A. annua</i>	青蒿油 <i>A. annua</i> oil
		艾 <i>A. argyi</i>	艾叶油 Blumea oil
伞形科 Umbelliferae	蕪本属 <i>Ligusticum</i>	川芎 <i>L. chuanxiong</i>	川芎油 <i>L. chuanxiong</i> oil

表 2 41 种精油对淡色库蚊的熏蒸活性 (三角瓶熏蒸法)

Table 2 Fumigation activity of 41 essential oils against female adults of *Culex pipiens pallens* (airtight fumigation in conical flask)

精油 Essential oils	击倒中时(95%置信限)(min) KT <sub>50</sub> (95% fiducial limit)	毒力回归方程 Regression equation	$\chi^2$ Chi-square value
冬青油 Wintergreen oil	4.01 (3.85–4.16)	$y = -0.8122 + 9.6422x$	2.96
桉叶油 <i>Eucalyptus robusta</i> oil	6.17 (5.85–6.49)	$y = -0.7626 + 7.2939x$	1.24
艾叶油 Blumea oil	6.32 (5.94–6.71)	$y = -0.9188 + 7.3924x$	5.96
薄荷油 Peppermint oil	6.57 (6.12–7.03)	$y = 0.0444 + 6.0636x$	1.17
八角茴香油 Star anise oil	6.85 (6.45–7.27)	$y = -1.0638 + 7.2544x$	1.16
蓝桉油 <i>Eucalyptus globulus</i> oil	6.97 (6.57–7.39)	$y = -3.0082 + 9.4944x$	1.68
白樟油 White camphor oil	7.11 (6.87–7.35)	$y = -6.0746 + 12.9988x$	0.06
柠檬草油 Lemongrass oil	7.14 (6.80–7.49)	$y = -3.1779 + 9.5794x$	0.68
冷榨桔子油 Cold squeeze mandarin oil	7.52 (7.02–8.06)	$y = -1.1003 + 6.9609x$	0.68
红桔油 Tangerine oil	7.63 (7.30–7.97)	$y = -4.2452 + 10.4749x$	0.39
蒸馏桔子油 Steam distillation mandarin oil	7.68 (7.29–8.07)	$y = -2.7035 + 8.7033x$	0.25
冷杉油 Fir needle oil	8.18 (7.45–8.97)	$y = 1.2681 + 4.0896x$	0.85
紫苏叶油 <i>Perilla frutescens</i> leaf oil	8.25 (7.88–8.63)	$y = -2.4071 + 8.0822x$	0.34
迷迭香油 Rosemary oil	9.01 (8.62–9.41)	$y = -4.3065 + 9.7468x$	0.07
芳樟油 Linaloe wood oil	9.29 (8.87–9.71)	$y = -5.3043 + 10.6464x$	0.95
白兰叶油 <i>Michelia alba</i> leaf oil	9.54 (9.07–10.01)	$y = -3.7429 + 8.9265x$	0.17
山苍子油 <i>Litsea cubeba</i> oil	9.95 (9.25–10.68)	$y = -2.1408 + 7.1580x$	0.15
依兰油 Ylang ylang oil	10.4 (9.78–11.05)	$y = -2.3520 + 7.2282x$	0.16
香樟油 Hosho oil	10.48 (10.08–10.90)	$y = -4.4759 + 9.2849x$	0.37
留兰香油 Spearmint oil	10.67 (10.06–11.30)	$y = -1.6016 + 6.4210x$	0.32
八角叶油 Star anise leaf oil	10.86 (10.41–11.33)	$y = -7.5917 + 12.1542x$	3.1
熏衣草油 Lavender oil	11.37 (10.95–11.81)	$y = -5.6207 + 10.0584x$	3.21
大蒜油 Garlic oil	12.28 (10.65–14.15)	$y = 1.0782 + 3.6004x$	0.37
橙叶油 Petitgrain oil	12.49 (11.38–13.69)	$y = -0.8395 + 5.3255x$	0.34
冬柠檬油 Winter lemon oil	12.75 (12.19–13.32)	$y = -6.8877 + 10.7538x$	3.25
柠檬桉油 Lemon eucalyptus oil	14.39 (13.69–15.12)	$y = -5.4231 + 9.0005x$	0.11
肉豆蔻油 Nutmeg oil	15.03 (14.38–15.70)	$y = -6.0299 + 9.3715x$	0.34
茶树油 Tea tree oil	15.04 (14.52–15.56)	$y = -9.2845 + 12.1350x$	0.39
玳玳花油 Dai-dai flower oil	16.8 (15.64–18.05)	$y = -2.3796 + 6.0220x$	0.05
细叶桉油 <i>Eucalyptus tereticornis</i> oil	18.83 (17.98–19.70)	$y = -10.1138 + 11.8558x$	0.46
玳玳叶油 Dai-dai leaf oil	19.27 (18.54–20.01)	$y = -9.2232 + 11.0701x$	0.24
丁香花蕾油 Clove bud oil	20.31 (19.29–21.38)	$y = -6.3321 + 8.6650x$	0.01
川芎油 <i>Ligusticum chuanxiong</i> oil	20.97 (19.15–22.96)	$y = -1.0259 + 4.5592x$	0.24
松节油 Turpentine oil	26.81 (25.24–28.47)	$y = -10.7080 + 10.9980x$	0.03
青蒿油 <i>Artemisia annua</i> oil	27.72 (25.98–29.56)	$y = -9.2367 + 9.8677x$	0.46
白柠檬油 Lime oil	30.01 (28.70–31.36)	$y = -8.5456 + 9.1697x$	0.13
丁香罗勒油 Eugenol type basil oil	30.2 (27.98–32.59)	$y = -15.4608 + 13.8246x$	0.14
肉桂油 Cinnamon oil	33.11 (31.23–35.09)	$y = -7.8877 + 8.4792x$	1.43
香茅油 Citronella oil	40.42 (36.52–44.72)	$y = -0.4935 + 3.4194x$	0.49
缬草油 Valerian oil	43.75 (41.38–46.24)	$y = -12.3293 + 10.5605x$	0.64
丁香叶油 Clove leaf oil	54.24 (47.61–61.79)	$y = -6.7477 + 6.7736x$	0.09

精油供试浓度为 12  $\mu\text{L/L}$ ; 各处理均设重复 3 次, 每重复 20 头试虫;  $\chi^2_{0.05,3} = 7.815$ 。The concentration of essential oil was 12  $\mu\text{L/L}$ ; each treatment had 3 replicates, with 20 mosquitoes for each replicate;  $\chi^2_{0.05,3} = 7.815$ .



2.2 密闭圆筒法对 26 种植物精油熏蒸效果的评价结果

在卫生害虫防控剂产品开发中,如蚊香、气雾剂等,熏蒸效果的评价以国标推荐的密闭圆筒熏蒸法为主。基于进一步开发的目的,根据 2.1 节的结果,选定  $KT_{50}$  在 15 min 内的 26 种精油,采用国标法(密闭圆筒熏蒸法)进一步评价了对淡色库蚊的熏蒸效果。

结果(表 3)表明,冬青油、艾叶油、薄荷油、桉叶油和蓝桉油等 5 种精油对淡色库蚊具有较强的熏蒸活性,  $KT_{50}$  在 25 min 以内,其中,冬青油熏蒸效果最好,  $KT_{50}$  为 16.91 min;薰衣草油、香樟油、芳樟油、紫苏叶油、松节油、迷迭香油和白樟油等 7 种精油的  $KT_{50}$  在 25 ~ 35 min 之间,效果一般;而留兰香油、柠檬草油、大蒜油等 14 种精油的  $KT_{50}$  在 35 min 以上,效果较差。

表 3 26 种精油对淡色库蚊的熏蒸活性(密闭圆筒法)  
Table 3 Fumigation activity of 26 essential oils against female adults of *Culex pipiens pallens* (hermetic round canister method)

精油 Essential oils	击倒中时(95%置信限)(min) $KT_{50}$ (95% fiducial limit)	毒力回归方程 Regression equation	$\chi^2$ Chi-square value
冬青油 Wintergreen oil	16.91 (15.62 – 18.29)	$y = -5.3251 + 8.4072x$	0.28
桉叶油 <i>Eucalyptus robusta</i> oil	18.43 (17.78 – 19.10)	$y = -8.0012 + 10.2730x$	0.67
蓝桉油 <i>Eucalyptus globulus</i> oil	19.48 (18.95 – 20.01)	$y = -18.4081 + 18.1518x$	5.14
艾叶油 Blumea oil	21.20 (20.40 – 22.02)	$y = -10.3939 + 11.6070x$	0.67
薄荷油 Peppermint oil	22.57 (21.85 – 23.29)	$y = -10.5459 + 11.4862x$	0.33
迷迭香油 Rosemary oil	27.44 (26.32 – 28.60)	$y = -12.1875 + 11.9492x$	0.39
白樟油 White camphor oil	29.40 (28.45 – 30.38)	$y = -10.3861 + 10.4782x$	0.86
芳樟油 Linaloe wood oil	29.41 (28.10 – 30.78)	$y = -7.9469 + 8.8160x$	0.25
香樟油 Hosho oil	30.71 (29.88 – 31.55)	$y = -14.7405 + 13.2726x$	1.40
松节油 Turpentine oil	32.72 (31.10 – 34.41)	$y = -5.3412 + 6.8269x$	0.06
薰衣草油 Lavender oil	33.38 (32.27 – 34.51)	$y = -10.8351 + 10.3943x$	0.95
紫苏叶油 <i>Perilla frutescens</i> leaf oil	33.79 (32.49 – 35.13)	$y = -15.1344 + 13.1706x$	0.39
留兰香油 Spearmint oil	43.89 (41.79 – 46.08)	$y = -12.9391 + 10.9226x$	0.69
依兰油 Ylang ylang oil	45.05 (42.64 – 47.57)	$y = -9.0994 + 8.5262x$	0.64
白兰叶油 <i>Michelia alba</i> leaf oil	45.20 (43.04 – 47.45)	$y = -7.1617 + 7.3480x$	0.35
红桔油 Tangerine oil	47.36 (45.85 – 48.91)	$y = -12.2899 + 10.3199x$	0.17
山苍子油 <i>Litsea cubeba</i> oil	52.02 (50.58 – 53.48)	$y = -20.2071 + 14.6880x$	0.31
大蒜油 Garlic oil	55.88 (54.80 – 56.98)	$y = -27.2493 + 18.4568x$	1.6
冷榨桔子油 Cold squeeze mandarin oil	57.32 (53.94 – 60.91)	$y = -4.9764 + 5.6738x$	0.86
蒸馏桔子油 Steam distillation mandarin oil	58.85 (56.18 – 61.64)	$y = -9.7835 + 8.3533x$	0.01
八角茴香油 Star anise oil	59.95 (52.36 – 68.61)	$y = -9.8769 + 8.3683x$	0.52
冬柠檬油 Winter lemon oil	60.73 (57.90 – 63.69)	$y = -10.6170 + 8.7569x$	1.17
八角叶油 Star anise leaf oil	62.03 (59.19 – 65.00)	$y = -11.0635 + 8.9609x$	0.15
柠檬桉油 Lemon eucalyptus oil	64.83 (62.43 – 67.30)	$y = -16.8918 + 12.0832x$	0.27
柠檬草油 Lemongrass oil	79.04 (52.45 – 119.11)	$y = -0.4555 + 2.8745x$	0.11
橙叶油 Petitgrain oil	81.33 (71.93 – 91.95)	$y = -8.6760 + 7.1592x$	0.34

精油供试浓度为 12  $\mu\text{L/L}$ ; 各处理均设重复 3 次, 每重复 20 头试虫;  $\chi^2_{0.05,3} = 7.815$ 。The concentration of essential oil was 12  $\mu\text{L/L}$ ; each treatment had 3 replicates, with 20 mosquitoes for each replicate;  $\chi^2_{0.05,3} = 7.815$ .

### 3 讨论

本研究测定了 17 科 41 种植物精油对淡色库蚊的熏蒸活性, 密闭三角瓶熏蒸法测定表明紫苏叶油等 26 种精油的  $KT_{50}$  小于 15 min; 而密闭圆筒法进一步确认了冬青油、艾叶油、薄荷油、桉叶油、蓝桉油等 5 种精油对淡色库蚊的熏蒸活性较强。经文献查阅, 发现国内外对其杀蚊活性报道不多, 多见其驱蚊作用, 如: 艾叶油是中国传统的驱蚊植物; 薄荷油中分离的 1, 8-桉叶素具有良好的驱蚊效果 (Ding and Sun, 1983; Amer and Mehlhorn, 2006; Erler *et al.*, 2006); 蓝桉油对埃及伊蚊幼虫具有毒杀活性 (Park *et al.*, 2011), 对埃及伊蚊、斯氏按蚊和致倦库蚊的成蚊有驱避作用 (Amer and Mehlhorn, 2006)。

在密闭圆筒法测定下, 5 种精油的熏蒸效果低于我国电热蚊香片室内药效评价 B 级标准 ( $KT_{50} \leq 8.0$  min) (农业部农药检定所, 2009, 第 5 部分), 也低于气雾剂室内药效评价 B 级标准 ( $KT_{50} \leq 5.0$  min), 但大量研究表明, 精油复配往往具有增效作用, 如柠檬草油、花椒油和香草醛混用具有明显的驱蚊增效作用 (Kim *et al.*, 2012), 且已有的精油类驱蚊产品也是多种精油的复配剂, 如: Termimx® ALLCLEAR® Sidekick 是 10.5% 肉桂油、13% 丁香酚、21% 香叶油、5.3% 薄荷和 2.6% 柠檬草油的混剂; Super Band™ 的主要成分为 15% 菲律宾香叶油、5% 印尼柠檬草油和 2% 香茅油。鉴于此, 有必要进一步开展冬青油、薄荷油、艾叶油、蓝桉油和桉叶油之间及它们与其他植物精油的混配增效作用研究, 有可能得到高活性的配方组合, 开发出具有应用前景的精油类卫生害虫防控剂, 尽快服务于蚊虫的无公害治理。

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